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SOME THOUGHTS ON THE TRANSFER OF TECHNOLOGY FROM DEVELOPED TO LESS-DEVELOPED NATIONS

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Until very recently, economists interested in the process of economic development have devoted little attention to a critical analysis of the role and implications of the transfer of technology from rich to poor nations. Apart from the tired cliches about the importance of "structural change" and "modernization", the literature on economic development has failed, in my opinion, to come to grips with the following fundamental question: is it basically in the best long-run interests of less-developed countries to be totally dependent on imported technology from industrialised nations in view of the former's many unique demographic, political and socio-economic conditions? More specifically, given the relative abundance of manpower, the gradual but inexorable drift of population from rural to urban areas, and the growing problems of urban unemployment, is it sensible for less developed countries to be passive recipients of production techniques whose very design was the result of a rational response to a diametrically opposite resource configuration?

In this paper, we shall attempt to analyse the nature and mechanism of technological transfer with a view towards answering the above questions and towards formulating a realistic alternative.

The Choice of Techniques: General Considerations

One aspect of the process fo technological transfer which has received extensive treatment in the development literature concerns the type of techniques which <u>should</u> be chosen by countries characterized by abundant labour and scarce capital (or foreign exchange). Generally speaking, two arguments have been advanced to support the proposition that the less-developed countries should use more labour-intensive techniques than those in use in the advanced countries.

The first argument based on neo-classical theoretical assumptions about factor substitutability, contends that less-developed nations should use more labour-intensive techniques because of the very different "shadow" factor price ratios that prevail in the poor nations. The economic rationale usually provided for this argument is the standard textbook assertion that static efficiency requires the equilibration of marginal rates of factor substitution with the (implicit) wage-rental ratios. Consequently, since wage-rental ratios are relatively low in less-developed countries, more labour-intensive techniques of production would seem desirable.

Unfortunately for many supporters of the neo-classical theory, the actual range of techniques available to many industries is extremely narrow with the result that substitution possibilities are, in fact, very limited. However, this limited substitutability is by no means inherent in the nature of the products produced. Rather, the actual range of available techniques is largely dictated by the nature of existing capital equipment. Since existing equipment is designed by capital goods industries in response to resource requirements and factor price ratios in advanced nations, very labour-using techniques are hard to come by. The important point here is that these labour-intensive techniques are by no means infeasible from a technical point of view. But they are <u>inefficient</u> from an economic point of view <u>in the advanced nations</u> and, therefore, are not produced. We will expound upon this argument later in the paper.

An additional reason why entrepreneurs in less developed countries choose techniques involving less than optimal labour-intensity arises out of the actual mechanics of technological transfer. Foreign suppliers of equipment and know-how have a strong tendency to transfer to the developing countries the production techniques and equipment tested by their own experience and requirements. There are two aspects to this phenomenon, one purely technical, the other primarily economic. From the technical point of view, the problem of inappropriate choice frequently arises out of the inability of the enterprise importing the know-how to formulate its requirements properly and to make a well-considered evaluation of alternatives offered by foreign technology with regard to various sources of capital equipment. For example, even though the finance for a new firm may come from Country "A", the most appropriate equipment to utilize in the operation may be produced in Country "B".

On the more specifically economic side, the basis problem is how to adapt foreign production techniques and equipment to the resource endowments of less developed countries. The early Japanese experience in adapting technology to available resources and skills and in developing the necessary conversion capabilities has often been cited as a model for developing countries. Japan also pioneered in the adaptation of equipment to employ large numbers of relatively unskilled village labour. For example, at the turn of the century, it imported second-hand textile machinery from England and used large numbers of workers to mend broken threads and repairmen to keep the older equipment running. In addition, the Japanese Government excercised considerable influence over foreign investment and licensing with a view towards maintaining Japanese industry on a technological par with world competition while still accelerating labour absorption. Unfortunately in many contemporary developing nations the prevalence of market imperfections at the factor level (e.g. urban wage rates do not truly reflect urban labour's opportunity cost), and the existence of certain institutional characteristics and government policies often lead to "mistaken" technological transfers. Government industrial development measures and controls such as investment licensing, export bonuses, import duties, and foreign exchange licensing often represent substantial capital subsidies and may have far-reaching effects on the capital-intensity of techniques chosen by individual firms.

The second argument for the use of labour-intensive techniques is somewhat more institutional than the first. Here it is contended that not only is the adoption of the most advanced capital-intensive technologies unwise from the viewpoint of optimal resource allocation, but also from the practical standpoint that the social, intellectual, and physical environment of less-developed countries is not conducive to the efficient utilization of these modern technologies. Lacking a labour force attuned to the unique requirements of specialization, an adequate indigenous managerial class intimately acquainted with modern techniques of organization, and a large class of skilled and semi-skilled "fundi" able to carry out the continuous maintenance of sophisticated but fragile modern equipment, most less-developed countries, it is argued, would be better served by "intermediate technologies" - i.e. those whose factor requirements lie somewhere "in-between" the most modern capital-intensive and the more primitive labour-intensive varieties. Viewed together, both the neo-classical and institutional arguments lead to the conclusion that indiscriminate introduction of the most advanced technologies is not only economically unwise but practically infeasible.

While both of the above arguments have intrinsic merit, they each fail to recognize a basic and crucial fact about technological choice in less-developed countries, namely, that the vast majority of the equipment used in the less-developed countries must be imported from the developed nations. As a result of this one-way transfer of technology, the range of actual choice is to a large extent limited by the technical specifications of imported equipment. Thus the argument for choosing very labour-intensive techniques is undermined by the fact that most new equipment is actually relatively labour-saving and therefore inherently undesirable, while the older, more labour-using equipment of an "intermediate" nature is either no longer being produced or is limited in supply and expensive to maintain. Moreover, the historical dynamics of technological transfer are such that over time one might reasonably expect that as long as less developed nations must rely on industrialized countries for their techniques of production,[1] all imported equipment, both new and used, is likely to have a long-run labour-saving bias. Consider the following formulation.

A Model of Technological Transfer[2]

We may view the technological transfer process in terms of a two country (i.e. developed and less developed) "vintage" capital model in which all capital goods are produced in the developed country and in which there is labour-saving technological progress embodied in newer vintages. Furthermore, we shall assume that equilibrium prevails in the capital goods market in the developed countries so that prices of equipment of different vintages adjust so as to equalize all profit rates in the developed country. This existence of equilibrium in the capital goods market plus the fact that each new vintage uses smaller amounts of labour per unit of output means that equipment prices must be such that the annual costs per unit of output are inversely related to the age of the machine, i.e., older machines have successively lower unit capital costs.

This can be seen in the following simple algebraic demonstration. Suppose there were two machines each with one year of life remaining. The newer vintage, j, has a lower labour coefficient than the older vintage, i, but equilibrium requires equipment prices to adjust so that $r_i = r_j$ where r is the profit rate. We therefore have the following relationships:

$$r_i = \frac{1 - wL_i}{p_i} = \frac{1 - wL_j}{p_j} = r_j$$

where L is the labour-output ratio, p is the price of capital per unit of output and w is the wage rate. Rearranging, we get $\frac{1 - wL_i}{1 - wL_j} = \frac{p_i}{p_j}$ and since by assumption $L_i > L_j$ it follows that $p_i < p_j$. This result can be extended to allow for situations of uneven life although the algebra is more complicated.

It follows from the above that given machinery prices determined entirely on the basis of the economic parameters of developed countries, the choice of equipment in less developed countries will depend essentially upon whether their own wage rates are low enough to offset the higher labour productivity on the new equipment. The ability of less-developed nations to benefit from choosing among alternative vintage equipment that is still economically productive in the developed countries results from the fact that the formers lower wage costs can lead to different profit rates per unit of investment on different vintages whereas equilibrium in the capital market precludes differential profit rates in the developed nation. Even equipment which is economically obsolete in the developed country may still yield positive profits in the less developed country and thus justify their importation at some positive price.

This is one reason why one typically finds a whole range of used equipment, some of which is domestically obsolete, being exported from the developed countries. However, in order to simplify the following analysis, we shall assume that the range of technical choice at any point in time is bounded by the factor intensities of the only two types of machines exported, namely, the most modern currently produced capital intensive vintage and say, the marginal or oldest technically productive "second-hand" labour-intensive vintage.

An important implication of the above analysis which needs to be emphasized strongly is that regardless of which technology is most efficient from the static context, the fact that the range of choice is being dictated by the technological mandates of factor price configurations and expectations in the developed nations demonstrates that over time there will be an inherent labour-saving bias in the whole process. In effect, the dynamics of technological choice faced by less-developed countries might be depicted by the following diagram. In Figure 1, ray t represents the factor proportions associated with the currently produced technology and (t - m) reflects the factor proportions on the vintage

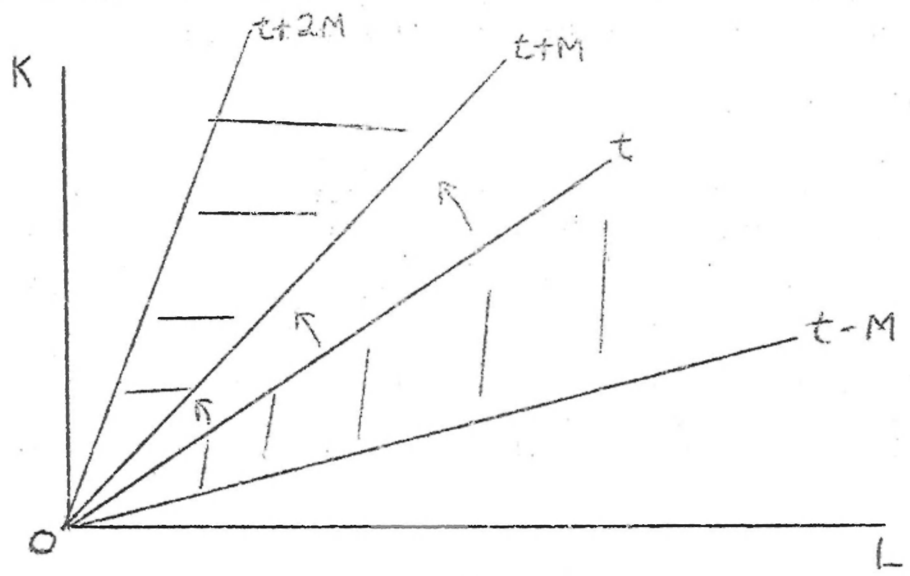

Figure 1

which is being scrapped by the developed country, where m represents the average age of the developed nation's capital stock. Over time this year's technology becomes the scrapped technology of m years hence, so that the triangular "pencil" formed by points t, O, and (t-m) shown in Figure 1 rotates to the left, e.g., to (t + 2m), O, (t + m), with an appropriate renumbering of the isoquants to reflect the continued progress of technology. The implication is clear. Since less-developed nations must import their technology from developed countries, they are forced to follow the bias inherent in this process regardless of whether or not such a process is in their long run interests.

Viewed in terms of the dynamics of technological transfer depicted above, the forceful but static argument that poor nations might profitably adopt used equipment to accelerate the process of labour absorption emerges as somewhat myopic.[3] This argument would be valid if output remained constant and capital did not depreciate. However, with output growing and replacement as well as net investment being required, even the extreme assumption that all gross investment is satisfied by the continuous importation of used equipment, i.e., the most labour-intensive then available, will still imply an increasing divergence between output and employment growth rates since the used equipment itself exhibits diminishing labour coefficients over time. Consequently, given the present abundance of labour and the prospective rapid increase in the potential industrial labour force, it follows that regardless of whether the used equipment is actually economically more efficient in terms of static unit costs than the modern capital-intensive equipment, the prospects for significant long-run labour absorption in the industrial sector become rather dubious.

The question then arises as to what are the alternatives. In our representation of the process of technological transfer, as long as the less-developed countries have no control over the direction and speed of technical change, the goals of industrial growth with significant labour absorption will be exceedingly difficult to realize. We have already alluded to the problem of the direction of technological change, i.e., that it is dictated by the factor scarcities of advanced countries and therefore tends to have a continuous labour-saving bias, but the question of the speed at which new techniques are introduced is also of great importance.

Consider an industry whose factor prices would seem to dictate than any expansion in output would most efficiently be met by further purchases of used equipment of vintage (t-m) in Figure 1. Although such expansion would be desirable, it is often not feasible as (t-m) type equipment is no longer being produced and the original store of it has either been completely depreciated or is extremely hard to come by. Moreover, given the structure of world trading patterns, as long as capital goods production is concentrated almost exclusively in developed countries, the relatively insignificant demands of poor nations for these goods will have only a negligible impact on both current production decisions about the type of machine to be produced and, more importantly, on the direction that factor saving bias will take in the future. It is for these reasons that we now will argue for the creation of domestic capital goods industries in less developed countries in which equipment production is geared to their own long-run technological requirements.

The Importance and Practicality of Locally Developed Technology

As we have seen, the mechanism and dynamics of technological transfer are such that less developed countries have little or no influence on either the factor bias or speed of technological change. In effect, they are passive recipients of a foreign technology. In spite of the lip-service which is given to the great importance of creating employment in the 'modern" sector, these nations are almost powerless to achieve this industrial employment objective. While the methods of transfer most commonly used do foster the importation of technical "know-how" and can therefore be a valuable short-term measure, this transfer does nothing to equip the recipient country to work out its own technologies in the future. The dependence of less-developed countries on foreign sources of equipment supply are perpetuated rather than progressively reduced. Instead, the practices that should be encouraged are those which would help to strengthen the poorer nations' capacity to develop technology at the national level. What is needed is not merely technical know-how but "creative" know-how.

The question of establishing domestic technological capacity has rarely been given serious consideration in the development literature. Even when it has been discussed, the emphasis has been largely in terms of saving foreign exchange and comparing costs of domestic production with that of equipment currently produced in the industrialized nations.[4] Abstracting from foreign exchange considerations (which can often be very important), the adoption and encouragement of a domestic machine producing industry capable of producing efficient labour-using techniques for other industries is justified in its own right when considered in the context of our earlier discussion of the speed and direction of technical change in the developed nations. Let us state explicitly that the establishment of this industry is not put forth as a solution to the employment problem at the cost of decreasing the rate of growth of output through the adoption of technologically dominated techniques. Rather, it is proposed on the assumption that both output and employment growth can be accelerated. Specifically, we would argue that less-developed countries should produce their own machinery, copying initially the earlier more labour-intensive designs of the industrialized countries. This would provide the possibility of eliminating much of the conflict between output and employment growth while avoiding the important difficulty of designing new, labour-using machinery. By duplicating earlier equipment, less developed nations would derive the benefit of controlling both the direction and speed of technical change in their own countries. In effect, this would reverse the direction of technical progress since the current trends in the developed countries would no longer be a determining feature of the factor using bias in the less-developed countries. The copying of older industrial production techniques would be capital saving <u>vis-a-vis</u> the equipment which may be currently imported from the developed nations. Moreover, if urban unemployment is eventually eliminated, the existence of a domestic capital goods industry allows the adoption of more recent labour-saving techniques to be introduced at a speed consonant with changing domestic factor availabilities. In effect, then, the domestic production of capital goods would allow output expansion to continue along process (t-m) in Figure 1 as opposed to the forced adoption of more capital intensive techniques due to the unavailability of vintage (t - m) equipment. Not only would this process alleviate the employment lag but it also could well be a major source of external economies to the non-capital goods sector, especially in providing skilled workers to these other sectors.[5] In addition, the possibilities of altering the received blueprints of developed nations in a labour-intensive way is greater with the existence of a domestic capital goods industry. Finally, another possible benefit derived from duplicating equipment which has previously been produced is the absence of the need for a large corps of engineers who can design new machinery, although undoubtedly some engineers would still be required.

Although it is often thought to be a capital-intensive branch, machinery production is in fact one of the more labour-intensive industrial branches in most economies. For example, in the United States where the most sophisticated equipment in the world is produced, the capital-labour ratio in the machine producing branches is relatively low.[6] Perhaps more interesting from the point of view of less devleoped countries is the very low capital-labour ratio found for the Japanese machinery industry in 1951 as shown in Table 1. Of 21 branches, only 7 had lower capital-labour ratios. One explanation of this phenomenon lies in the nature of the machine producing technology. It is most often not amenable to mass production methods as production takes place in reponse to specific orders embodying differing specifications, while mass production requires a continuous flow of similar products. The foundation of the misconception of the branch's capital intensity lies in the confusion between the direct and total input structure. While some branches which produce important inputs to the machine branch, particularly metals, are themselves very capital intensive, there is no necessity to produce these domestically, even if domestic machines are produced. Not only is the machinery branch not a heavy user of capital, but it offers the advantage that small scale production may be relatively efficient. The absence of substantial economies of scale is the

Table 1

JAPAN MACHINERY PRODUCTION, 1951

	Direct Capital-Labour Ratio		Direct Capital-Labour Ratio
Petroleum products	1.200	Metal mining	.172
Coal products	.682	Fishing	.170
Non-ferrous metal	.363	Machinery and electrical equipment	.161
Chemicals	.338	Apparel	.132
Iron and steel	.337	Textiles	.131
Nonmetallic mineral products	.298	Paper	.120
Nonmetallic minerals	.199	Rubber	.119
Processed foods	.193	Lumber and wood	.111
Grain mill products	.193	Printing	.093
Shipbuilding	.174	Leather	.068
Transport equipment	.174		

SOURCE: Institute for Social and Economic Research, Osaka University. (mimeo)

result of the specialized, non-mass production nature of the industry, although for some types of machinery, particularly agricultural equipment, large scale production may be possible. On the other hand, as Rosenberg has suggested, there may be "economies of specialization," i.e., firms producing only a limited range of machinery such as looms may acquire greater facility in producing even small numbers of machines. Such specialization may, of course, be limited by the size of the domestic market. Here, however, the possibilities for division of labour among many of the less-developed countries are obvious. The possibilities of a coordinated development of a capital goods industry in the East African Community come immediately to mind. Moreover, as we shall suggest below the existence of capital goods industries in these countries could provide an important means of transmission of technical knowledge relevant to their own specific resource endowments.

The main precondition for the establishment of a capital goods industry is the creation of an appropriate pool of skilled and semi-skilled labour if it does not already exist. Unfortunately relatively little systematic effort has been devoted to analyzing the training requirements for given industries. However, work on the United States economy by Richard Eckaus provides some guidelines to the type and intensity of training likely to be required.[7] Using education and vocational training requirements for occupations prepared by the U.S. Bureau of Labour Statistics, Eckaus calculated the average amount of training required by workers in each branch of U.S. industry. While the average years of schooling required is 11, similar to that in most branches, the average period of vocational training in the machine producing industries is 1.77, one of the longest. These figures conform with the general impression that this branch is particularly skill intensive. However, from the viewpoint of establishing capital goods production capacity, Eckaus' data probably overstates the preparation period as they include the training of large numbers of engineers who are involved in the designing and testing of equipment.[8] Engineers and other technicians would presumably be needed only in much smaller proportions if designs were in fact copied from the developed countries. Moreover, the U.S. data reflect skills needed in producing products such as turbines and sophisticated machine tools, whereas we would hardly suggest that such complicated products be produced during the early stages of a capital goods industry. Even ignoring these biases, the education and training requirements are less formidable when one allows for the fact that the absolute numbers of workers to be involved in the branch is likely to be small. While the costs of training may be larger than those for other branches, they may be viewed as an investment whose returns are likely to be quite high.

Although developed countries might well have a comparative advantage in the production of such equipment, there are numerous reasons why they are unlikely to engage in such production. Foremost among these is the fact that capital goods producers typically envision the markets of the less-developed nations as being highly volatile due to political as well as economic instability. Since there is no domestic market for this equipment and since the variance in expected returns is likely to be substantial given the aforementioned uncertainties, the costs of creating the necessary additional capacity may not be warranted, given the assured returns from the domestic market.

Assuming the will and the capacity to establish the branch, the question arises as to whether its output likely to be competitive with that of foreign producers? First, it must be emphasized that in an important sense this question is not entirely relevant as there would be no comparable equipment of old design currently being produced in the developed countries for export to the less-developed countries. It should be noted, however, that if the labour using machines actually produced in the less-developed country also resulted in higher unit capital costs than the labour-saving equipment of the advanced countries, then it would pay to forego the establishment of the capital goods industry unless there was a reasonable presumption that infant industry arguments had validity. But, as shown below, available evidence suggests that even where competitive sophisticated equipment is being produced, adverse cost conditions are not likely to be the case. This is not too surprising since we have seen that the most important factor of production is skilled labour and its price is likely to be very low in comparison with comparable labour in the advanced countries. For example, a recent ECLA study in Brazil calculated the cruzeiro prices of domestically produced machines and machine components per dollar of imported machines to be as shown in Table 2.

At the time of the study the free market rate was 180 cruzeiros per dollar and the rate established under the exchange auction system was 250 cruzeiros per dollar. Thus most of the goods were produced at a price which was less than the international price using even the lower exchange rate and all were as cheap or cheaper when the auction rate, which probably is a better indicator of scarcity value, is used.

Table 2

Domestic Production Cost in Cruzeiros
Divided by Dollar Cost of Imported Equipment

Type of Equipment	Cruzeiros per Dollar
Metal structures, direct fired furnaces	160.00
Pressure vessels (towers and pressure storage)	163.00
Large-diameter welded tubes	170.00
Storage tanks; steam generator-mixers	172.00
Electrical equipment - electricity ducts; tubing - steel and forged iron tubes; refractories and thermal insulation material	180.00
Heat exchanges and surface condensers	183.00
Cyclones	185.00
Travelling cranes; lifts and lifting tackle	190.00
Tubing - connections - expansion joints	200.00
Pumps and compressors	220.00
Electrical equipment - motors and transformers	250.00

SOURCE: United Nations, The Manufacture of Industrial Machinery and Equipment in Latin America I. Basic Equipment in Brazil (New York, 1963), p. 20.

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Similarly, the machine tool branch in Argentina has been exceptionally successful. Output has expanded rapidly at prices low enough to allow almost $2 million of exports annually during the years from 1963 to 1965.[9] And, an analysis of the structure of the Israeli economy for 1958 indicated that the real costs of saving a dollar of imports in the machinery branch were among the lowest to be found in any branch in industry, despite the small size of the sector.[10] Finally, support is provided in a study by R. Soligo and J. Stern[11] of the effective tariff rate (the rate of protection of value added) in Pakistan. Their data show that the effective rate of protection of machinery is the lowest for any group of products in Pakistan. Nevertheless, the rate of growth of output in this branch has been very rapid. Thus, despite the lack of tariff protection, profitability in machine production must be quite high, implying that the branch may have a comparative advantage.

Thus, available evidence, although by no means complete, does conform to our initial expectation that less-developed countries may well be competitive even in the production of the most modern capital goods.

Moreover, apart from the advantages to be derived from the production of efficient, labour intensive machines, other benefits would certainly be significant. Foreign exchange shortages frequently interrupt development programs resulting in either an interruption in the investment program or a reduction in the current rate of production as intermediate imports are cut back. Assuming that the shortage results from a foreign exchange gap rather than a savings constraint, the existence of domestic capital producing capacity eliminates to an important extent the need to obtain foreign exchange in order to transform savings into real investment goods.[12] Finally, even if few individual less-developed countries could expect to produce the full range of capital goods, trade among them could still eliminate the foreign exchange bottleneck which, given current geographic distribution of capital goods production, often is tantamount to a lack of exports to the advanced countries.

The dynamic benefits obtainable from equipment production should also be mentioned. One result of the recent outpouring of literature on production functions and technological change has been to focus attention on the likelihood that technical change is often embodied in new equipment.[13] Assuming this approach to contain a substantial amount of descriptive power, the question arises as to the source of these improvements. There is historical evidence that a large part of this change has its origin in the capital goods branches themselves, those actually employed in the branch constituting an important source of new ideas.[14] However, there is still considerable scope for further investigation of this important question.

Finally, the existence of a capital goods sector may constitute a necessary condition for changes in design which respond to domestic relative factor scarcities in the economy. Although there are at present clear directions in which a capital-saving technology could develop,[15] the machine producing industry in the developed nations is, for a variety of reasons, unlikely to follow this course. Thus, in the final analysis, the long run economic performance of less developed nations might depend largely on the successful adoption and the continued growth of a domestic capital goods industry whose technological production is more attuned to their own unique needs and objectives.

FOOTNOTES

1. See A. Maizels, Industrial Growth and World Trade (Cambridge; England:, 1965), Table 10.9, p. 276 for the statistics of LDC dependence on industrial nations for capital goods.

2. The following model is more fully developed in H. Pack and M.P. Todaro "Technological Transfer, Labour Absorption, and Economic Development," Oxford Economic Papers, November, 1969.

3. For an excellent and thoughtful earlier statement of the conditions under which it might be profitable to adopt used equipment, see A.K. Sen, "On the Usefulness of Used Machines," The Review of Economics and Statistics, XLVI, 3 (August, 1962), pp. 346-8. See also Jagdish Bhagwati, The Economics of Underdeveloped Countries (New York: World University Library, 1966), p. 195 and Netherlands Economic Institute, "Second Hand Machines and Economic Development," (May, 1958).

4. For example, see United Nations, The Manufacture of Industrial Machinery and Equipment in Latin America I. Basic Equipment in Brazil (New York, 1963).

5. Nathan Rosenberg has argued that in the United States there were major external benefits derived from the expansion of the capital goods industry. See his "Technological Change in the Machine Tool Industry, 1840-1910," Journal of Economic History, XXIII (December 1963), pp. 414-43.

6. See W.W. Leontief, Input-Output Economics (London: Oxford University Press, 1966), pp. 129-133.

7. Richard Eckaus, "Economic Criteria for Education and Training," Review of Economics and Statistics (May 1964).

8. However, variations in natural conditions, e.g., mineral availabilities may still require some additional designing and testing of equipment.

9. ECLA, La Fabricacion de Maquinerias y Equipos Industriales en America Latina: IV Las Maquinas-Herranuentas en la Argentina (Santiago de Chile, 1966), pp. 73-77, cited in Carlos Diaz-Alejandro, Essays on the Economic History of the Argentine Republic, forthcoming.

10. M. Bruno, Interdependence, Resource Use and Structural Change in Israel (Jerusalem: Bank of Israel), 1962.

11. "Tariff Protection, Import Substitution and Investment Efficiency in Pakistan," Pakistan Development Review (Summer), 1965.

12. For an early statement of the problem which anticipated much of the recent "two gap" literature see E.D. Domar, "A Soviet Model of Growth" in Essays in the Theory of Economic Growth (New York: Oxford University Press, 1957).

13. See R.M. Solow, "Investment and Technical Progress" in Mathematical Methods in the Social Sciences (Stanford, 1960). For a recent discussion of the difficulty of actually measuring such change, see D. Jorgenson, "The Embodiment Hypothesis," Journal of Political Economy (February 1966).

14. N. Rosenberg, "Capital Goods, Technology and Economic Growth," Oxford Economic Papers (November 1963), provides many examples from U.S. economic history.

15. For a suggestive analysis of these possibilities see G.K. Boon, Economic Choice of Human and Physical Factors in Production (Amsterdam: North Holland Publishing Co., 1964), pp. 59-65.